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Ceramic Collaborations around the World

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Abstract International collaboration can be an integral part of a research project. It can add scientific expertise or interdisciplinarity, enhance equipment and facilities; and strengthen the training and education of students. In recognition of these benefits, the National Science Foundation (NSF) of the United States has supported researchers in many different modes. One option for ceramists is the Materials World Network (MWN) program. Today, ~24% of the active projects in the Ceramics Program (CER) of NSF's Division of Materials Research (DMR) are funded through the MWN program (or its precursors). Each project includes participants from two or more countries and collectively they include researchers from 16 countries. This year an additional 33 ceramic proposals, including renewals, were merit-reviewed in panels and seven awards were made. Characteristics of the best proposals include synergistic pairings of interests and expertise between international partners, detailed plans for student exchanges, activities to broaden the participation of groups under-represented in science, and cutting-edge creative and original research ideas. As well, NSF supports many international activities through the Office of International Science and Engineering (OISE) including regional opportunities. Instrumentation and facilities supported by NSF, particularly those in Materials Science and Engineering, are often accessible on an international basis.

Keywords: International - Collaboration - Cooperation - Group - Ceramics - Synthesis -Characterization - Competitiveness

1 Introduction

It is well accepted that international collaborations have been beneficial for materials research.[1] The incentives for collaborating world-wide are many-fold[2-3] and may be categorized into three general areas: increased scientific capability, advantages for scientific progress overall, and benefits on the international front (Table I). The first category, increased scientific capability, is almost always the main motivation for individual researchers. They can see advantages in sharing equipment, data, and ideas, and in tackling large or complex problems with a team approach. One additional possible benefit of broader interaction is the creation of a more universal scientific language between different scientific communities. The second category, advantages for scientific community, deals with the inherent benefits to scientific progress that come from sharing. Examples include using the best equipment, discussions between leading scientific researchers, rapid sharing and validation of results, and the avoidance of unnecessary duplicative efforts. These advantages are often recognized by scientific organizations and professional societies. The last category, benefits for international relations and prosperity, acknowledges the role science and engineering has on policy, health, sustainability, and economic growth. Research on materials can impact standards, exchange/trade, research priorities and industrial development. Naturally international cooperation can lead to a better understanding and appreciation of different cultures and values. These collaborations can be beneficial in covering the spectrum from fundamental understanding, materials development, device or product design, through manufacturing, and in taking a multidisciplinary approach that includes contributions from physics, chemistry, materials science, engineering and the life sciences.[3] In short, international cooperation can be instrumental in improving the standard of living and quality of life.

Recent changes in key intersecting technologies, particularly the Internet, fiber-optics, and the PC, have caused dramatic shifts in how many people[4] conduct business on a global basis.[5] For these reasons, it is now easier for researchers to collaborate with their preferred partners around the world, and so science and engineering research has also become increasingly global.

Professional societies, such as the International Union for Vacuum Science, Technique and Applications (IUVSTA);[6] the Materials Research Society;[7] and the American Ceramic Society[8] foster international collaborations in materials research. Many funding agencies world-wide support international research.

For example, in the USA, many if not all, major federal departments and agencies supporting materials research have international ties.[2] The Office of Naval Research (ONR) has an arm called 'ONR Global'. It serves as an international presence for ONR that actively seeks opportunities to promote science and technology collaboration of mutual benefit between the USA and researchers around the globe.[9] The Air Force Office of Scientific Research International Office

Table I. Advantages of International Collaborations

Increased scientific capability	• Development of new professional skills and approaches[10] (such as, creative practices,[11] innovation and entrepreneurship) from the experience of working in different research environments • Access to data, facilities, and resources[3] that transcend national boundaries[2] • Development of strategic alliances to contribute to or develop world-leading capabilities[3] • Exchange of expertise; Establishment of mutually beneficial research partnerships;[3] Building more stable relations among communities by creating a universal language[2]
Advantageous for scientific progress overall	• Collaboration with the best researchers[3] and brightest minds • Promotion of the USA as a world center for research and innovation, and attraction of the best researchers • More open timely communication, sharing and validation of research findings[2] • Awareness of advances, discoveries and new insights being made world-wide,[2] and consequently making appropriate research investment decisions[3] • Avoidance of unnecessary duplication of effort
Beneficial for international relations and prosperity	• Influence of the international research agenda;[3] Coordination and negotiation with foreign bodies[2] • Contribution to world issues,[3] international material standards and public policies[3] (relating to areas such as intellectual property rights, data exchange, trade, visas and immigration)[2] • Greater appreciation of role of an industrialized nation in meeting challenges for health and sustainability of world resources • Attraction of global industries[3] and promotion of economic growth[2]

(AFOSR/IO) has a mission to expand the horizon of scientific knowledge through international liaison and leadership to discover, shape, and champion basic science that will create revolutionary breakthroughs to profoundly impact future Air Force capabilities.[12] Similarly, the National Institutes of Health (NIH) has an international component called 'The Fogarty International Center' that addresses global health challenges through innovative and collaborative research and training programs, and supports and advances the NIH mission through international partnerships.[13] The Department of Energy participates in several international partnerships.[14] In the remainder of this article, opportunities for international collaboration through the USA's National Science Foundation (NSF) are outlined.

2 The National Science Foundation in the United States of America

NSF is an independent USA federal agency. With an annual budget of ~$6 billion, NSF is the funding source for ~20% of all federally supported basic research activities conducted by America's colleges and universities.[15] NSF's mission is fulfilled chiefly by issuing ~10,000 limited-term grants each year to fund specific research proposals that have been judged the most promising by a rigorous and objective merit-review system. Most of these awards go to individuals or small groups of investigators, but others provide funding for research centers, instruments and facilities that allow scientists, engineers and students to work at the outermost frontiers of knowledge.

The congressional Act of 1950, as amended, authorizes and directs NSF to initiate and support: (1) Science and engineering research and education programs at all levels and in all fields of science and engineering; (2) Basic research fundamental to the engineering process; (3) Programs to strengthen research potential; and (4) An information base appropriate for development of national and international policy.[16] Over time, legislation and presidential directives have added new requirements including: supporting efforts in the Arctic and Antarctic; addressing issues of equal opportunity in science and engineering, and fostering the interchange of scientific and engineering information nationally and internationally.

This last goal, to foster the interchange of information among scientists and engineers in the United States and foreign countries, is important since science and engineering addresses global questions of significant societal importance. Today's research requires investigators working collaboratively across agencies and international organizations to apply the results of basic research to long-standing global challenges such as epidemics, natural disasters and the search for alternative energy sources. "The U.S. has long benefited from an open-door policy that welcomes science and engineering talent from abroad. Other nations are now adopting this policy, as well as providing incentives for students to pursue their education at home or to return from abroad. Increasing international competition and workforce mobility, combined with a surge in international collaboration in science and engineering research, continue to alter the science and engineering landscape worldwide. To lead within this broader global context, the U.S. science and engineering workforce must build greater capacity for productive international collaboration."[1]

According to NSF's Director, Dr. Arden Bement, international collaborations have the following characteristics: (1) global collaboration can accelerate materials discovery and design, to the benefit of the entire international materials community, (2) people create new knowledge and advance technology most effectively when they engage collectively in the process of imagination and discovery, and (3) we can design and foster a global network to achieve common, long-term goals.[17]

3 Access to NSF's Equipment and Facilities

A starting point for many collaborative efforts is the filling of an essential need, whether it is intellectual expertise or access to specialized facilities. In recognition of the exchange processes involved in collaborations, NSF has encouraged the development of accessible resources. For example, the Materials Research Science and Engineering Centers (MRSEC) often have experimental and computational facilities[18] that they are willing to share in exchange for operating costs.

As well, NSF supports the operation of national user facilities: research facilities with specialized instrumentation available to the scientific materials research community.[19] These facilities provide research capabilities located at only a few highly specialized laboratories in the nation. They include facilities and resources for research using high magnetic fields, ultraviolet and x-ray synchrotron radiation, neutron scattering, and nanofabrication. No charge is made for access to these facilities; time is allotted according to the scientific merit and viability of proposals submitted directly to each facility.[20]

Also, there is open access to NSF's Award Abstracts Database which has useful information about NSF awards.[21]

4 Fostering New Collaborations

There are several funding mechanisms to strengthen efforts with new international collaborators. NSF's Office of International Science and Engineering (OISE) is a starting point for information on these options.[22] OISE directly administers a number of solicitations that support international research and education activities (Table II) and it is home for several regional opportunities (e.g., see Table III). Contacts at NSF are assigned for specific countries or regions.[23] NSF maintains overseas offices in Paris, Tokyo, and Beijing; although they do not review proposals or administer awards, they can facilitate international efforts. These offices have three major roles: (1) Promote collaboration, (2) Serve as a liaison between NSF and agencies, institutions, and researchers, and (3) Monitor and report on science and engineering developments and policies.

Table II. OISE Programmatic Activities

Developing Global Scientists and Engineers (International research experiences for students, and Doctoral dissertation enhancement projects)
International Research Fellowship Program (for postdoctoral fellows)
Pan-American Advanced Studies Institutes
East Asia and Pacific Summer Institutes
Partnerships for International Research and Education (PIRE)
International Planning Visits and Workshops

Investigators with current NSF grants may request supplemental funding to add international collaboration to existing projects.[24] A recent program in the Engineering (ENG) directorate, International Research and Education in Engineering (IREE), provided supplemental funding to current ENG awardees to support international travel by early-career researchers in the USA. The goals were to give researchers an international research experience and perspective, and strengthen research interaction between USA institutions and their foreign counterparts.[25]

Table III. Opportunities in Africa

Africa, Near East & South Asia (ANESA) Regional Opportunities	workshops, short-term planning visits, dissertation enhancement, and research experiences for students
E-mail	anesainfo@nsf.gov
Telephone	(703) 292-8707
FAX	(703) 292-9176
AFRICA	Activities focus on human resource development and capacity building in research and education. Participation of junior investigators from both the United States and the host country is strongly encouraged. Topics that benefit from the region's unique biological, environmental, geological, anthropological, and cultural resources are of special interest. Proposals may combine research and education into one project, such as the REU (Research Experiences for Undergraduates) Site on Lake Tanganyika in Tanzania, coordinated through the International Decade for the East African Lakes (IDEAL).[26] Other areas of regional interest include materials research, global climate change, natural resources management, and the International Long-Term Ecological Research (ILTER) Program.[27]
Contact Person	Elizabeth Lyons

5 Launching and Continuing Research Projects with Foreign Collaborators

Investigators seeking funding for international collaborative research may include an international component in proposals submitted to their relevant NSF research program,[28] or apply directly to programs focused on international collaboration. Several programs encourage an international component as part of the original proposal, see e.g., Integrative Graduate Education and Research Traineeship Program (IGERT)[29] and Chemical Bonding Centers (CBC).[30]

One new and expanding option for ceramists is the Materials World Network (MWN) program.[31] NSF will accept proposals from American universities and colleges addressing collaborations between researchers from the USA and participating countries or regions with a clear relevance to research supported by the Division of Materials Research (DMR). Concurrently, investigators at foreign research institutions should submit to the counterpart funding organization in their country or region a request for support of their side of the collaboration. NSF will consider support of all appropriate research costs for the USA side of such collaborations, with the expectation that funding or research organizations from the appropriate countries or regions will consider supporting the costs of the non-USA participants.

All NSF proposals are reviewed according to the two review criteria: intellectual merit and broader impacts.[32] MWN proposals have additional criteria: (1) The value added by the proposed international collaboration in materials and condensed matter research, and (2) The extent to which collaboration integrates research and education and promotes diversity. Preference will be given to proposals where: intellectual efforts in USA and abroad are balanced, and students and other junior researchers participate in international research experiences. Strong preference will be given to proposals with support from both NSF and the counterpart organization.

Today, ~24% of the active projects in the Ceramics Program (CER)[33] in DMR are funded through the MWN program (or its earlier versions: Inter-American Materials Collaboration (CIAM) and NSF-Europe). Projects vary in length, from two to four years, and support from NSF ranges from $66,000 to $323,000 per year. Each project includes participants from two or more countries and collectively they include researchers from 16 countries: Argentina, Brazil, China, France, Germany, Hungary, India, Mexico, Poland, Portugal, Russia, Singapore, Spain, Sweden, Switzerland, and the United Kingdom. An additional project, co-funded with DMR's new biomaterials program (BMAT),[34] includes participants from Egypt, Portugal and Senegal. Although projects with European collaborators are well-represented in the ceramics portfolio, and to a lesser extent so are projects with South Americans, connections to researchers in other regions of the world are currently not.

This fiscal year an additional 33 ceramic proposals, including renewals, were merit-reviewed in panels and seven awards were made (Table IV). Characteristics of the best proposals include synergistic pairings of interests and expertise between international partners, detailed plans for student exchanges, activities to broaden the participation of groups under-represented in science, and cutting-edge creative and original research ideas.

Table IV. Fiscal Year 2007 MWN Awards in CER

Award Number	Title	PI	Institution	Country/ies of Collaborators
0710643	Measurement of Local Charge Distributions in Materials	Marks, Laurence	Northwestern University	UK
0709831	Novel Strain Control in Thick Epitaxial Nancomposite Films	Wang, Haiyan	Texas Engineering Experiment Station	UK
0710523	Discovery of Low Conductivity Oxides by Integrated Simulation and Experimentation	Clarke, David	University of California-Santa Barbara	China, UK
0709740	Nanometric Effects at Ultra-Small Crystallite Size: Investigation of Low-Temperature Protonic Conductivity in Dense Functional Oxide Ceramics	Munir, Zuhair	University of California-Davis	Germany
0709887	Catalyst Materials Synthesis at Accessible High Temperatures and Pressures	Kiely, Christopher	Lehigh University	UK
0710630	Ceramic Composites from Natural and Synthetic Scaffolds	Faber, Katherine	Northwestern University	Spain
0710564	An International Collaborative Educational and Research Program in the Study of Mixed Glass Former Phenomena in Materials	Martin, Steve	Iowa State University	Sweden, Germany

6 International Networks: Partnerships and Institutes

OISE's program, Partnerships for International Research and Education (PIRE), seeks to catalyze a cultural change in USA institutions by establishing innovative models for international collaborative research and education. Proposals may request up to five years of support, with annual budgets ≤$500,000. The program enables American institutions to establish collaborative relationships with international groups or institutions in order to engender new knowledge and discoveries at the frontier and to promote the development of a globally-engaged, American scientific and engineering workforce. The program supports forward-looking research whose success comes from all partners providing unique contributions to the research endeavor. It is also intended to facilitate greater student preparation for and participation in international research collaboration, and to contribute to the development of a diverse, globally-engaged, USA science and engineering workforce.[35] So far, two competitions have been held resulting in 32 grants.

DMR's program, International Materials Institutes (IMIs), is similar to PIRE in that it focuses on supporting international networking in order to enhance international collaboration between USA researchers and educators and their counterparts worldwide; however, its focus is limited to materials research and education.[36] To date, two competitions have been held and in total, six awards were made. Each IMI is expected to have an annual budget for $500,000 to $1,000,000 per year. Awards are made for an initial period of up to five years. Funding for the fifth year is contingent upon the outcome of a comprehensive review during the fourth year. These university-based Institutes advance fundamental materials research by coordinating international research and education projects to meet global and regional needs. They provide a research environment that will attract leading scientists and engineers. "The Institutes' long term goal is the creation of a worldwide network in materials research and the development of a new generation of scientists and engineers with enhanced international leadership capabilities. A critically important aspect of an IMI is its potential impact on advancing materials research on an international scale and developing an internationally competitive generation of materials researchers, and this distinguishes an IMI from other materials research centers that NSF supports."[12]

7 Conclusions

International collaboration has been a critical part of materials research. Collaboration can add scientific expertise or interdisciplinarity, enhance equipment and facilities; and strengthen the training and education of students. As the world becomes more globally-engaged, the development of a diverse science and engineering workforce able to operate in teams, comprised of partners from different nations and cultural backgrounds, takes on greater importance. Professional societies facilitate linkages internationally through scientific meetings and distribution of information, and many funding agencies have international offices or branches that foster partnerships. In recognition of the many benefits of international cooperation, the National Science Foundation (NSF) of the USA supports world-wide accessible facilities and interaction in different modes.

Researchers at all levels, from students through professors, have opportunities through NSF for international activities. Programs exist that address the forging of new collaborations, on-going co-operations and expanding networks. Some of these activities are housed in the international office (OISE), while others are found within disciplinary programs. For example, DMR has developed an international program (MWN) that supports more than a hundred research projects. Today, about one in four of the active projects in ceramics in DMR is funded through the MWN program (or its earlier versions). The best proposals have common characteristics: synergy of interests and expertise between international partners, plans for meaningful student exchanges, engagement of under-represented groups, and ideas for transformational research.

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References

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[1] AIP Bull. of Sci. Policy News, Number 136 (Nov. 14, 2000) http://www.aip.org/fyi/2000/fyi00.136.htm; National Academy project, "Assessment of and Outlook for New Materials Synthesis and Crystal Growth" http://www8.nationalacademies.org/cp/projectview.aspx?key=48740
[2] Toward a More Effective Role for the U.S. Government in International Science and Engineering, NSB report 01-187 (2001) http://www.nsf.gov/nsb/documents/2002/nsb01187/start.htm
[3] UK Research Councils, "International Partnerships in Action" (2004); "International Research – A Strategy for the UK Research Councils" (2007) www.rcuk.ac.uk/cmsweb/downloads/rcuk/publications/international.pdf
[4] Some 3 billion people in places like rural India, rural China, and Africa are largely unaffected by the technologies and socioeconomic changes. See comments about developing countries in ref. 5 below.
[5] Thomas L. Friedman, The World Is Flat: A Brief History of the Twenty-first Century (Release 3.0), Farrar, Straus and Giroux (2007), ISBN 0-374-29278-7; http://en.wikipedia.org/wiki/The_World_is_Flat
[6] IUVSTA is a Union of national member societies whose role is to stimulate international collaboration in the fields of vacuum science, techniques and applications and related multi-disciplinary topics including solid-vacuum and other interfaces. http://www.iuvsta.org/iuvsta2/index.php
[7] International Materials Research Opportunities: http://www.mrs.org/s_mrs/sec.asp?CID=1735&DID=38988
[8] E.g., with the International Congress on Ceramics series (http://www.icc2.org/)
[9] ONR Global: http://www.onrglobal.navy.mil/
[10] Toward a More Effective Role for the U.S. Government in International Science and Engineering, NSB report 01-187 (2001) http://www.nsf.gov/nsb/documents/2002/nsb01187/start.htm
[11] UK Research Councils, "International Partnerships in Action" (2004); "International Research – A Strategy for the UK Research Councils" (2007) www.rcuk.ac.uk/cmsweb/downloads/rcuk/publications/international.pdf
[12] Air Force international: http://www.wpafb.af.mil/library/factsheets/factsheet.asp?id=8971
[13] NIH International: http://www.fic.nih.gov/about/index.htm
[14] DOE International hydrogen and fuel cell activities: http://www.hydrogen.energy.gov/international.html
[15] NSF: http://www.nsf.gov/about/glance.jsp
[16] Investing in America's Future, NSF Strategic Plan FY 2006-2011, NSF 06-48 (Sept. 2007). http://www.nsf.gov/pubs/2006/nsf0648/nsf0648.jsp
[17] A.L. Bement, Materials World Network Symposium, Cancun, Mexico (Aug. 22, 2005); http://www.nsf.gov/news/speeches/bement/05/alb050822_materials.jsp
[18] MRSEC facilities: http://www.mrsec.org/facilities/
[19] DMR user facilities: http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5359&org=DMR
[20] See e.g., http://www.magnet.fsu.edu/usershub/proposals/index.html, and http://www.nnin.org/nnin_howtostart.html
[21] Searchable database of NSF awards: http://www.nsf.gov/awardsearch/
[22] Office of International Science and Engineering (OISE): http://www.nsf.gov/div/index.jsp?div=OISE
[23] Country and regional representatives in OISE: http://www.nsf.gov/od/oise/country-list.jsp
[24] Supplemental funding information: http://www.nsf.gov/pubs/policydocs/papp/gpg_2.jsp#IID2b and/or https://www.fastlane.nsf.gov/NSFHelp/flashhelp/fastlane/FastLane_Help/fastlane_help.htm#supplemental_funding_request_introduction.htm
[25] ENG IREE supplement: http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=13705

[26] http://www.geo.arizona.edu/nyanza
[27] http://www.lternet.edu
[28] L.D. Madsen, "Ceramics at the National Science Foundation - Trends and Opportunities", Global Roadmap for Ceramics and Glass Technology, pp. 127-142, Wiley (June 2007).
[29] IGERT: http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=12759
[30] CBC: http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=9186 and http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=13635
[31] Materials World Network solicitation: http://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf07574&org=NSF
[32] Notification about NSF merit review criteria: http://www.nsf.gov/pubs/1999/iin125/iin125.html
[33] CER: http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5352&org=DMR&from=home
[34] BMAT: http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=13699&org=DMR&from=home
[35] PIRE in OISE: http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=12819&org=OISE&from=home
[36] IMI in DMR: http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5328&from=fund